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METHOD FOR PRODUCING AN OPTICAL GRATING ON AN OPTICAL CONDUCTOR AND DEVICE COMPRISING A GRATING OF THIS TYPE

[0001] This application is the national phase under 35 U.S.C. § 371 of PCT International Application No. PCT/DE00/03078 which has an International filing date of September 6, 2000, which designated the United States of America, the entire contents of which are hereby incorporated by reference.

Field of the Invention

[0002] The invention generally relates to a method for producing at least one optical grating, in particular a Bragg grating, on an optical conductor. The conductor is preferably fixed at least at two fixing points, which are arranged at a distance from one another The grating is then preferably produced on the fixed conductor between the fixing points.

Background of the Invention

[0003] In known methods of the aforementioned type, the optical conductor is a glass fiber which is prestressed between the two fixing points during the production of the grating and is released again after the production of the grating on the fiber.

[0004] An optical Bragg grating was first produced using a standing optical wave of the radiation of an argon laser in an optical monomode fiber (see K.O. Hill et al.: "Photosensitivity in optical fiber waveguides: Application to reflection filter fabrication", Appl. Phys. Lett., vol. 32, 1978, pp 647 - 649). This produces relatively long fiber gratings with a length of, for example, about one meter.

[0005] Later it was proposed to produce a Bragg grating in a fiber by transverse UV irradiation of an optical fiber. In this case, a holographic method was used in which the superposition of two beams of UV radiation with plane waves generated an interference fringe pattern which was used to expose the fiber.

[0006] The two beams of UV radiation can be generated in different ways. The following arrangements have already been used:

- an interferometer with splitter mirror and three or more deflection mirrors (see G. Meltz, W.W. Morey, W.H. Glenn: "Formation of Bragg gratings in optical fibers by transverse holographic method", Opt. Lett. 14 (15), 1989, p 823);
- a mirror (Lloyd's mirror interferometer, see R. Kasyap et al.: "All-fiber narrow-band reflection gratings at 1550 nm", Electron. Lett. 26 (12), 1990, p 823 and/or B. Eggleton, P.A. Krug, L. Poladin: "Dispersion compensation by using Bragg grating filters with self induced chirp", Tech. Digest. Opt. Fib. Comm. Conf., OFC'94, 1994, p 227);

- a prism (Lloyd's prism interferometer, see Q. Zhang et al.: "Simple prism-based scheme for fabricating Bragg gratings in optical fibers", Opt. Lett. 19 (23), 1994, pp 2030 - 2032 and/or N.H. Rizvi, M.C. Gower: "Production of submicron period Bragg gratings in optical fibers using wavefront division with a biprism and an excimer laser source", Appl. Phys. Lett. 67 (6), 1995, pp 739 - 741);
- an interferometer with diffraction-optical beam splitter and two deflection mirrors;
- total reflection in a quartz glass body (see R. Kashap et al.: "A novel method of writing photo-induced chirped Bragg gratings in optical fibers", Electron. Lett. 12, 1994, pp 994 - 997).

[0007] Another known method includes the use of a phase mask for producing an interference fringe pattern (see K.O. Hill et al.: "Bragg gratings fabricated in photosensitive optical fiber by UV exposure through a phase mask", Appl. Phys. Lett. Vol. 62, 1993, pp 1035 -1037 and/or D.Z. Anderson et al.: "Production of in-fiber gratings using a diffractive optical element", Electron. Lett., vol. 29, 1993, pp 566 - 568). In this case, the fiber is fixed directly behind a phase mask made of quartz glass. A beam of UV radiation is sent through the phase mask. The UV radiation is diffracted at a grating structure of the phase mask. A plus first order of diffraction and a minus first order of diffraction are produced behind the grating structure of the phase mask. Superposition of the two orders of diffraction results in a UV interference fringe pattern. The fiber is irradiated by the fringe pattern. On account of the photosensitivity of the fiber, a periodic increase in refractive index arises in the irradiated regions of the fiber core.

[0008] A further method for producing a grating on a fiber is point by point exposure of the fiber (see K.O. Hill et al.: "Efficient mode conversion in telecommunication fiber using externally written gratings", Electron. Lett. 26 (16), 1990, p 1270 and/or B. Malo et al.: "Point by point fabrication of micro-Bragg gratings in photosensitive fiber using single excimer laser pulse refractive index modification techniques", Electron. Lett. Vol. 29, 1993, pp 1668 - 1669). In this case, it is important that the fiber does not experience any changes in its mechanical state during the relatively long time required for writing the grating into the fiber.

[0009] A general overview of the methods used heretofore can be found for example in K.O. Hill et al.: "Fiber Bragg Grating Technology Fundamentals and Overview", Journal of Lightwave Technology, Vol. 15, No. 8, August 1997, pp 1263 - 1276.

[0010] B. Malo et al.: "Apodised in-fiber Bragg grating reflectors photoimprinted using a phase mask", Electron. Lett., vol. 31, 1995, pp 223 - 224 and/or J. Albert et al.: "Apodisation of the spectral response of fiber Bragg gratings using a phase mask with variable diffraction efficiency", Electron. Lett., vol. 31, 1995, pp 222 - 223, disclose producing fiber gratings with exactly defined requirements imposed on the spectral properties by means of

apodisation; in this case, too, the fiber is initially restrained and is released again after the grating has been written into the fiber.

SUMMARY OF THE INVENTION

[0011] It is an object of an embodiment of the invention to show how an optical grating, in particular a Bragg grating, can be produced on an optical conductor in a simple manner. The grating may have an exactly defined and uniform grating constant.

[0012] This object can be achieved by, for example, an optical conductor durably fixed at the fixing points before the grating is produced. This is in contrast to the known methods in which a fiber is restrained before the grating is produced or written. It can be fixedly held prestressed to a greater or lesser extent during the writing process, and can be released again after the grating has been written, so that the fiber is only fixed temporarily rather than durably.

[0013] An embodiment of the invention is based on the insight that the procedure used heretofore of restraining and subsequently releasing the fiber after the production of the grating on the fiber device that mechanical stresses which persisted during said production are liberated again, or that new mechanical stresses are generated through handling of the fiber after release. These mechanical stresses lead to changes in the grating constant or period in the grating and thus to variation of the reflection or transmission spectrum. Mechanical stresses which act only in parts of the grating and, accordingly, influence only portions of the grating structure can drastically alter the spectral profile and thus call into question the usability of the relevant grating.

[0014] Undesired partial alterations of the grating constant also play a major part in a grating with exactly defined requirements imposed on the spectral properties, for example in a grating produced by apodisation or a particularly long fiber grating. In this case, too, such undesired partial alterations may be brought about by the fact that, during the production of such a grating, the fiber is firstly restrained and is released again after the production of the grating.

[0015] A method according to an embodiment of the invention advantageously ensures the stability of the grating constant and of all other parameters of the grating after the production of the grating on the optical conductor.

[0016] In one embodiment of the method according to the invention, the optical conductor is stress-free between the fixing points during the production of the grating. In another embodiment, the optical conductor is tensioned between the fixing points during the production of the grating.

[0017] An embodiment of the invention also provides an advantageous arrangement having a carrier body, an optical conductor and an optical grating, in particular a Bragg grating. The conductor can be fixed at least at two fixing points, which are arranged at a distance from one

another, on the carrier body. The grating can be formed on the fixed conductor between the fixing points. The conductor can be durably fixed on the carrier body at the fixing points, and the grating is a grating which is produced after the durable fixing of the conductor on the carrier body.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The invention is explained in more detail by way of example embodiments in the description below, with reference to the drawings, in which:

Figures 1a to 1d show a starting stage, two intermediate stages and an end stage of an exemplary embodiment of the method according to an embodiment of the invention,

Figures 2a and 2b show, in side view and plan view, respectively, a Bragg grating sensor produced by the method according to an embodiment of the invention and serving for measuring a temperature,

Figure 3 shows, in plan view, a Bragg grating sensor produced by the method according to an embodiment of the invention and serving for measuring an acceleration, and

Figure 4 shows, in side view, a temperature-stable Bragg reference grating produced by the method according to an embodiment of the invention.

[0019] The figures are diagrammatic and not to scale.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] In accordance with the starting stage of the method according to the invention and indicated in figure 1a, an optical conductor 1 is applied to a carrier body 2, which is illustrated in each case in side view in figures 1a to 1d, and is durably fixed at two fixing points 21, 21, which are arranged at a distance d from one other in the direction of a defined longitudinal axis 10 of the conductor 1, on the carrier body 2. This thereby produces the first intermediate stage of the method according to the invention as indicated in figure 1b.

[0021] On the conductor 1 thus fixed, an optical grating 11 (see figure 1d) is produced between the two fixing points 21, 21. To that end, it is possible to use, for example, any of the methods described in the prior art. By way of example, in accordance with figure 1c, the photosensitive conductor 1 is exposed with a beam of radiation 4, for example comprising UV light, sent through a phase mask 3. The radiation 4 impinging as a plane optical wave 41 on the mask 3 is diffracted at a grating structure 31 of the phase mask 3. Downstream of the grating structure 31 of the phase mask 3, a plus first order 32 of diffraction and a minus first order 33 of diffraction are produced, each of which respectively defines an interference fringe and which, taken together, form an interference fringe pattern 35. This fringe pattern 35 exposes the conductor 1 between the fixing points 21, 21 in such a way that the interference fringes defined by the borders 32 and 33 of diffraction periodically succeed one another in

the direction of the longitudinal axis 10 of the conductor 1. On account of the photosensitivity of the conductor 1, a respective increase in refractive index arises in each exposing interference fringe.

[0022] After this exposure of the conductor 1, the end stage of the method according to the invention as illustrated in figure 1d has been produced, in which the optical grating 11 is formed between the two fixing points 21, 21 of the carrier body 2 on the conductor 1. The optical grating is defined by local refractive index increases 110 which periodically succeed one another in the direction of the longitudinal axis 10 of the conductor 1.

[0023] A particular advantage of the described use of the phase mask 3 is to be seen in the fact that the phase mask 3 can be applied directly on the carrier body 2 and, unlike before, the conductor 1 in the form of the glass fiber need not be brought into position at a distance before the phase mask 3. Moreover, this procedure advantageously ensures a very precise position of a Bragg wavelength and of the other parameters of the grating 11, for example a spectral width, a degree of reflection, etc. of the grating 11. It is advantageous that, since the grating 11 is already fixed by a carrier body 2, these parameters no longer have to be set subsequently during installation.

[0024] In this way, it is also possible to produce two or more optical gratings 11 on the conductor 1 between the two fixing points 21, 21, to be precise at the same time and/or one after the other in time and/or spatially separate from one another and/or superposed on one another.

[0025] The fixing of the conductor 1 on the carrier body 2 at the two fixing points 21, 21 remains even after the production of the one or more gratings 11 and is not detached.

[0026] The optical conductor 1 is durably fixed on the carrier body 2 not subsequently but actually before the production of the one or more optical gratings 11.

[0027] The optical conductor 1 that is to be fixed on the carrier body 2 preferably does not yet have an optical grating, although at least one grating which is different from a grating 11 to be produced first may already be present on said conductor 1, but in that case it does not have the advantageous properties of the grating 11.

[0028] The optical conductor 1 is preferably an optical glass fiber, for example a monomode or multimode fiber and/or a core-cladding-glass fiber. The conductor 1 may also be an optical waveguide integrated on a substrate. The optical conductor 1 is preferably of elongate design in the direction of the longitudinal axis 10.

[0029] The optical conductor 1 can be held between the two the fixing points 21, 21 in such a way that it is stress-free during the production of a grating 11 between the fixing points 21. Preferably, the conductor 1 is freely suspended between the fixing points 21, 21 and the grating 11 is produced in the freely suspended conductor 1.

[0030] It is also expedient if the optical conductor 1 is stressed between the two fixing points 21, 21 during the production of the grating 11. Such prestressing is expedient because, as a result, the conductor 1 still remains extended even in the event of a mechanical load relief acting on it.

[0031] The carrier body 2 may be designed not only for fixing the conductor 1, but also for realizing specific functions.

[0032] If the carrier body 2 serves only for fixing the conductor 1, it may be of simple, for example integral, design. By contrast, if it has to fulfil specific further functions, for example functions of a Bragg grating sensor, the carrier body 2 may be of more complicated, in particular composite, construction. Thus, by way of example, mechanical levers, actuators or elements having characteristic thermal expansion coefficients for temperature compensation may be part of the carrier body 2.

[0033] A particular advantage of the method according to the invention is that the conductor 1 can be connected to the carrier body 2, for example by bonding, soldering, collapsing, etc., without special consideration being given to conductor stress, room temperature and subsequently desired grating parameters of the grating 11. In the case of a conductor 1 in the form of a quartz glass fiber, for example, a temperature required for fixing the conductor 1 on the carrier body may be up to 800°C, while a grating 11 to be produced after this fixing is already degraded from approximately 150°C and is even destroyed at higher temperatures. After the fixing of the conductor 1 on the carrier body 2 at a higher temperature, all that need be done is to wait until the temperature of the conductor 1 has fallen to below the temperature from which degradation or deformation of the grating 11 to be produced occurs.

[0034] The method according to an embodiment of the invention advantageously makes it possible generally to realize Bragg grating sensors for measuring a physical quantity, including, for example, a sensor for measuring a temperature, an acceleration, a force, an electrical current, an electric voltage, an electric field, a magnetic field, etc., and also, for example, a stable Bragg grating as optical wavelength reference, an accurate Bragg grating for application in telecommunications and/or a long period optical grating (Long Period Grating (LPG)) and applications thereof.

[0035] Figures 2a and 2b illustrate, in side view and plan view, respectively, an exemplary Bragg grating sensor produced by the method according to an embodiment of the invention and serving for measuring a temperature, figure 3 illustrates, in plan view, a Bragg grating sensor produced by the method according to an embodiment of the invention and serving for measuring an acceleration, and figure 4 illustrates, in side view, a temperature-stable Bragg grating produced by the method according to an embodiment of the invention as an optical wavelength reference.

[0036] Each of the two sensors and also the temperature-stable Bragg grating in each case has an arrangement having a carrier body 2, an elongate optical conductor 1 and a Bragg grating 11, the conductor 1 being fixed at two fixing points 21, 21, which are arranged at a distance d from one another, on the carrier body 2, and the grating 11 being formed on the fixed conductor 1 between said fixing points 21, 21, with the special feature that the conductor 1 is durably fixed on the carrier body 2 at the fixing points 21, 21, and the grating 11 is a grating which is produced after the durable fixing of the conductor 1 on the carrier body 2.

[0037] In the case of the sensor according to figures 2a and 2b, the carrier body 2 is preferably in one piece and is composed of quartz glass, for example. The conductor 1 is, for example, a glass fiber which is fixed durably to the body 2 between the two fixing points 21, 21, preferably under prestressing, and in which the Bragg grating 11 is formed between the two fixing points 21, 21. The glass fiber 1 is freely suspended between the two fixing points 21, 21. To that end, the carrier body 2 has a cutout 20 on its side facing the glass fiber 1, said cutout being bridged by the fiber 1. A temperature-dependent change in refractive index and expansion of the fiber 1 leads to a measurable shift in the Bragg wavelength of the grating 11 with the temperature. The expansion of the fiber 1 with the temperature can be amplified by a suitably chosen material of the carrier body 2.

[0038] The arrangement of the sensor according to figure 3 differs from that of the sensor according to figures 2a and 2b essentially only through the presence of an inertial mass M. Otherwise, the sensor according to figure 3 structurally corresponds to the sensor according to figures 2a and 2b, and parts which are identical in both sensors are designated in figure 3 by the same reference symbols as in figures 2a and 2b.

[0039] In the sensor according to figure 3, the mass M is connected to the fiber 1 and exerts an expanding and/or contracting force on the Bragg grating 11, formed on the fiber 1, when the carrier body 2 is moved under acceleration.

[0040] In the case of the arrangement of the temperature-stable Bragg grating according to figure 4, the carrier body 2 is of composite rather than integral design. The composite carrier body 2 has a substrate body 2' and two sub-carrier bodies 2", 2" which are fixed on the substrate body 2' and separated from one another by an interspace 22'. On the two sub-carrier bodies 2", 2", the conductor 1, likewise comprising a glass fiber for example, is fixed at the two fixing points 21, 21 in such a way that one fixing point 21 is situated on one sub-carrier body 2" and the other fixing point 21 is situated on the other sub-carrier body 2", that the conductor 1 bridges the interspace 22', and that the grating 11 formed on the conductor 1 is arranged above the interspace 22'.

[0041] The two sub-carrier bodies 2", 2" are fixed on the substrate body 2' in such a way that a section 20", 20" - adjoining the interspace 22' - of each sub-carrier body 2", 2" is not

connected to the substrate body 2' and can freely expand and/or contract in the event of a change in temperature relative to the substrate body 2'.

[0042] The material of the substrate body 2' and the material of the two sub-carrier bodies 2", 2" are coordinated with one another in such a way that the interspace 22' between the sub-carrier bodies 2", 2" is narrowed and/or widened on account of a temperature-dictated expansion and/or contraction of the sections 20", 20" of the two sub-carrier bodies 2", 2". By way of example, the sub-carrier bodies 2", 2" are composed of a material having a thermal expansion coefficient $\alpha > 0$ and the substrate body 2' is composed of a material having a smaller thermal expansion coefficient relative to said coefficient α, preferably a vanishingly small thermal expansion coefficient.

[0043] A narrowing of the interspace 22' brought about by a change in temperature counteracts an expansion of the conductor 1 and hence of the grating 11 brought about by the change in temperature. A widening of the interspace 22' brought about by a change in temperature counteracts a contraction of the conductor 1 and hence of the grating 11 brought about by the change in temperature.

[0044] The material of the substrate body 2', the material of the two sub-carrier bodies 2", 2" and the material of the conductor 1 are preferably coordinated with one another in such a way that the narrowing of the interspace 22' brought about by a change in temperature essentially exactly cancels the expansion of the conductor 1 and hence of the grating 11 brought about by the change in temperature, and the widening of the interspace 22' brought about by a change in temperature essentially exactly cancels the contraction of the conductor 1 and hence of the grating 11 brought about by the change in temperature.

[0045] This is the case, for example, if the material of the sub-carrier bodies 2", 2" and the material of the conductor 1 essentially have the same thermal expansion coefficient $\alpha > 0$ and if the thermal expansion coefficient of the material of the substrate body 2' is vanishingly small relative to said coefficient α.

[0046] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

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Description

Method for producing an optical grating on an optical conductor and arrangement having such a grating and such a conductor

The invention relates, according to the preamble of claim 1, to a method for producing at least one optical grating, in particular a Bragg grating, on an optical conductor, the conductor being fixed at least at two fixing points, which are arranged at a distance from one another, and the grating then being produced on the fixed conductor between said fixing points.

In known methods of the aforementioned type, the optical conductor is a glass fiber which is prestressed between the two fixing points during the production of the grating and is released again after the production of the grating on the fiber.

An optical Bragg grating was first produced by means of a standing optical wave of the radiation of an argon laser in an optical monomode fiber (see K.O. Hill et al.: "Photosensitivity in optical fiber waveguides: Application to reflection filter fabrication", Appl. Phys. Lett., vol. 32, 1978, pp 647 - 649). This produces relatively long fiber gratings with a length of, for example, about one meter.

Later it was proposed to produce a Bragg grating in a fiber by transverse UV irradiation of an optical fiber. In this case, a holographic method is used in which the superposition of two beams of UV radiation with plane waves generates an interference fringe pattern which is used to expose the fiber.

The two beams of UV radiation can be generated in different ways. The following arrangements have already been used:

- an interferometer with splitter mirror and three or more deflection mirrors (see G. Meltz, W.W. Morey, W.H. Glenn: "Formation of Bragg gratings in optical fibers by transverse holographic method", Opt. Lett. 14 (15), 1989, p 823);

- a mirror (Lloyd's mirror interferometer, see R. Kasyap et al.: "All-fiber narrow-band reflection gratings at 1550 nm", Electron. Lett. 26 (12), 1990, p 823 and/or B. Eggleton, P.A. Krug, L. Poladin: "Dispersion compensation by using Bragg grating filters with self induced chirp", Tech. Digest. Opt. Fib. Comm. Conf., OFC'94, 1994, p 227);

- a prism (Lloyd's prism interferometer, see Q. Zhang et al.: "Simple prism-based scheme for fabricating Bragg gratings in optical fibers", Opt. Lett. 19 (23), 1994, pp 2030 - 2032 and/or N.H. Rizvi, M.C. Gower: "Production of submicron period Bragg gratings in optical fibers using wavefront division with a biprism and an excimer laser source", Appl. Phys. Lett. 67 (6), 1995, pp 739 - 741);

- an interferometer with diffraction-optical beam splitter and two deflection mirrors;

- total reflection in a quartz glass body (see R. Kashap et al.: "A novel method of writing photo-induced chirped Bragg gratings in optical fibers", Electron. Lett. 12, 1994, pp 994 - 997).

Another known method consists in the use of a phase mask for producing an interference fringe pattern (see K.O. Hill et al.: "Bragg gratings fabricated in

photosensitive optical fiber by UV exposure through a phase mask", Appl. Phys. Lett. Vol. 62, 1993, pp 1035 - 1037

and/or D.Z. Anderson et al.: "Production of in-fiber gratings using a diffractive optical element", Electron. Lett., vol. 29, 1993, pp 566 - 568). In this case, the fiber is fixed directly behind a phase mask made of quartz glass. A beam of UV radiation is sent through the phase mask. The UV radiation is diffracted at a grating structure of the phase mask. A plus first order of diffraction and a minus first order of diffraction are produced behind the grating structure of the phase mask. Superposition of the two orders of diffraction results in a UV interference fringe pattern. The fiber is irradiated by said fringe pattern. On account of the photosensitivity of the fiber, a periodic increase in refractive index arises in the irradiated regions of the fiber core.

A further method for producing a grating on a fiber is point by point exposure of the fiber (see K.O. Hill et al.: "Efficient mode conversion in telecommunication fiber using externally written gratings", Electron. Lett. 26 (16), 1990, p 1270 and/or B. Malo et al.: "Point by point fabrication of micro-Bragg gratings in photosensitive fiber using single excimer laser pulse refractive index modification techniques", Electron. Lett. Vol. 29, 1993, pp 1668 - 1669). In this case, it is important that the fiber does not experience any changes in its mechanical state during the relatively long time required for writing the grating into the fiber.

A general overview of the methods used heretofore can be found for example in K.O. Hill et al.: "Fiber Bragg Grating Technology Fundamentals and Overview", Journal of Lightwave Technology, Vol. 15, No. 8, August 1997, pp 1263 - 1276.

B. Malo et al.: "Apodised in-fiber Bragg grating reflectors photoimprinted using a phase mask", Electron. Lett., vol. 31, 1995, pp 223 - 224 and/or

J. Albert et al.: "Apodisation of the spectral response of fiber Bragg gratings using a phase mask with variable diffraction efficiency",

Electron. Lett., vol. 31, 1995, pp 222 - 223, disclose producing fiber gratings with exactly defined requirements imposed on the spectral properties by means of apodisation; in this case, too, the fiber is initially restrained and is released again after the grating has been written into the fiber.

It is an object of the invention to show how an optical grating, in particular a Bragg grating, can be produced on an optical conductor in a simple manner, said grating having an exactly defined and uniform grating constant.

This object is achieved by means of the features specified in claim 1.

According to this solution, the optical conductor is durably fixed at the fixing points before the grating is produced, in contrast to the known methods in which a fiber is restrained before the grating is produced or written, is fixedly held prestressed to a greater or lesser extent during the writing process and is released again after the grating has been written, so that the fiber is only fixed temporarily rather than durably.
The invention is based on the insight that the procedure used heretofore of restraining and subsequently releasing the fiber after the production of the grating on the fiber means that mechanical stresses which persisted during said production are liberated again, or that new mechanical stresses are generated through handling of the fiber after release. These mechanical stresses lead to changes in the grating constant or period in the grating and thus to variation of the reflection or transmission spectrum. Mechanical stresses which act only in parts of the grating and, accordingly, influence only portions of the grating structure can drastically alter the spectral profile and thus call into question the usability of the relevant grating.

Undesired partial alterations of the grating constant also play a major part in a grating with exactly defined requirements imposed on the spectral properties, for example in a grating produced by apodisation or a particularly long fiber grating. In this case, too, such undesired partial alterations may be brought about by the fact that, during the production of such a grating, the fiber is firstly restrained and is released again after the production of the grating.

The method according to the invention advantageously ensures the stability of the grating constant and of all other parameters of the grating after the production of the grating on the optical conductor.

In one embodiment of the method according to the invention, the optical conductor is stress-free between the fixing points during the production of the grating, and, in another embodiment, the optical conductor is tensioned between the fixing points during the production of the grating.

The invention also provides an advantageous arrangement having a carrier body, an optical conductor and an optical grating, in particular a Bragg grating, the conductor being fixed at least at two fixing points, which are arranged at a distance from one another, on the carrier body, and the grating being formed on the fixed conductor between said fixing points, and which arrangement is characterized in that the conductor is durably fixed on the carrier body at the fixing points, and the grating is a grating which is produced after the durable fixing of the conductor on the carrier body.

The invention is explained in more detail by way of example in the description below, with reference to the drawings, in which:

Figures 1a to 1d show a starting stage, two intermediate stages and an end stage of an exemplary embodiment of the method according to the invention,

Figures 2a and 2b show, in side view and plan view, respectively, a Bragg grating sensor produced by the method according to the invention and serving for measuring a temperature,

Figure 3 shows, in plan view, a Bragg grating sensor produced by the method according to the invention and serving for measuring an acceleration, and

Figure 4 shows, in side view, a temperature-stable Bragg reference grating produced by the method according to the invention.

The figures are diagrammatic and not to scale.

In accordance with the starting stage of the method according to the invention and indicated in figure 1a, an optical conductor 1 is applied to a carrier body 2, which is illustrated in each case in side view in figures 1a to 1d, and is durably fixed at two fixing points 21, 21, which are arranged at a distance d from one other in the direction of a defined longitudinal axis 10 of the conductor 1, on the carrier body 2, thereby producing the first intermediate stage of the method according to the invention as indicated in figure 1b.

On the conductor 1 thus fixed, an optical grating 11 (see figure 1d) is produced between the two fixing points 21, 21. To that end, it is possible to use, for example, any of the methods described in the prior art.

By way of example, in accordance with figure 1c, the photosensitive conductor 1 is exposed with a beam of radiation 4, for example comprising UV light, sent through a phase mask 3. The radiation 4 impinging as a plane optical wave 41 on the mask 3

is diffracted at a grating structure 31 of the phase mask 3. Downstream of the grating structure 31 of the phase mask 3, a plus first order 32 of diffraction and a minus first order 33 of diffraction are produced, each of which respectively defines an interference fringe and which, taken together, form an interference fringe pattern 35. This fringe pattern 35 exposes the conductor 1 between the fixing points 21, 21 in such a way that the interference fringes defined by the borders 32 and 33 of diffraction periodically succeed one another in the direction of the longitudinal axis 10 of the conductor 1. On account of the photosensitivity of the conductor 1, a respective increase in refractive index arises in each exposing interference fringe.

After this exposure of the conductor 1, the end stage of the method according to the invention as illustrated in figure 1d has been produced, in which the optical grating 11 is formed between the two fixing points 21, 21 of the carrier body 2 on the conductor 1, said optical grating being defined by local refractive index increases 110 which periodically succeed one another in the direction of the longitudinal axis 10 of the conductor 1.

A particular advantage of the described use of the phase mask 3 is to be seen in the fact that the phase mask 3 can be applied directly on the carrier body 2 and, unlike before, the conductor 1 in the form of the glass fiber need not be brought into position at a distance before the phase mask 3. Moreover, this procedure advantageously ensures a very precise position of a Bragg wavelength and of the other parameters of the grating 11, for example a spectral width, a degree of reflection, etc. of the grating 11. It is advantageous that, since the grating 11 is already fixed by a carrier body 2, these parameters no

longer have to be set subsequently during installation.

In this way, it is also possible to produce two or more optical gratings 11 on the conductor 1 between the two fixing points 21, 21, to be precise at the same time

and/or one after the other in time and/or spatially separate from one another and/or superposed on one another.

The fixing of the conductor 1 on the carrier body 2 at the two fixing points 21, 21 remains even after the production of the one or more gratings 11 and is not detached.

The optical conductor 1 is durably fixed on the carrier body 2 not subsequently but actually before the production of the one or more optical gratings 11.

The optical conductor 1 that is to be fixed on the carrier body 2 preferably does not yet have an optical grating, although at least one grating which is different from a grating 11 to be produced first may already be present on said conductor 1, but in that case it does not have the advantageous properties of the grating 11.

The optical conductor 1 is preferably an optical glass fiber, for example a monomode or multimode fiber and/or a core-cladding-glass fiber. The conductor 1 may also be an optical waveguide integrated on a substrate. The optical conductor 1 is preferably of elongate design in the direction of the longitudinal axis 10.

The optical conductor 1 can be held between the two the fixing points 21, 21 in such a way that it is stress-free during the production of a grating 11 between the fixing points 21. Preferably, the conductor 1 is freely suspended between the fixing points 21, 21 and the grating 11 is produced in the freely suspended conductor 1.
It is also expedient if the optical conductor 1 is streesed between the two fixing points 21, 21 during the production of the grating 11. Such prestressing is

expedient because, as a result, the conductor 1 still remains extended even in the event of a mechanical load relief acting on it.

The carrier body 2 may be designed not only for fixing the conductor 1, but also for realizing specific functions.

If the carrier body 2 serves only for fixing the conductor 1, it may be of simple, for example integral, design. By contrast, if it has to fulfil specific further functions, for example functions of a Bragg grating sensor, the carrier body 2 may be of more complicated, in particular composite, construction. Thus, by way of example, mechanical levers, actuators or elements having characteristic thermal expansion coefficients for temperature compensation may be part of the carrier body 2.

A particular advantage of the method according to the invention is that the conductor 1 can be connected to the carrier body 2, for example by bonding, soldering, collapsing, etc., without special consideration being given to conductor stress, room temperature and subsequently desired grating parameters of the grating 11. In the case of a conductor 1 in the form of a quartz glass fiber, for example, a temperature required for fixing the conductor 1 on the carrier body may be up to 800°C, while a grating 11 to be produced after this fixing is already degraded from approximately 150°C and is even destroyed at higher temperatures. After the fixing of the conductor 1 on the carrier body 2 at a higher temperature, all that need be done is to wait until the temperature of the conductor 1 has fallen to below the temperature from which degradation or deformation of the grating 11 to be produced occurs.

The method according to the invention advantageously makes it possible generally to realize Bragg grating sensors for measuring a physical quantity, including, for example, a sensor for measuring a temperature, an acceleration, a force, an electrical current, an

electric voltage, an electric field, a magnetic field,

etc., and also, for example, a stable Bragg grating as optical wavelength reference, an accurate Bragg grating for application in telecommunications and/or a long period optical grating (Long Period Grating (LPG)) and applications thereof.

Figures 2a and 2b illustrate, in side view and plan view, respectively, an exemplary Bragg grating sensor produced by the method according to the invention and serving for measuring a temperature, figure 3 illustrates, in plan view, a Bragg grating sensor produced by the method according to the invention and serving for measuring an acceleration, and figure 4 illustrates, in side view, a temperature-stable Bragg grating produced by the method according to the invention as an optical wavelength reference.

Each of the two sensors and also the temperature-stable Bragg grating in each case has an arrangement having a carrier body 2, an elongate optical conductor 1 and a Bragg grating 11, the conductor 1 being fixed at two fixing points 21, 21, which are arranged at a distance d from one another, on the carrier body 2, and the grating 11 being formed on the fixed conductor 1 between said fixing points 21, 21, with the special feature that the conductor 1 is durably fixed on the carrier body 2 at the fixing points 21, 21, and the grating 11 is a grating which is produced after the durable fixing of the conductor 1 on the carrier body 2.

In the case of the sensor according to figures 2a and 2b, the carrier body 2 is preferably in one piece and is composed of quartz glass, for example. The conductor 1 is, for example, a glass fiber which is fixed durably to the body 2 between the two fixing points 21, 21, preferably under prestressing, and in which the Bragg grating 11 is formed between the two fixing points 21,

21. The glass fiber 1 is freely suspended between the two fixing points 21, 21. To that end,

the carrier body 2 has a cutout 20 on its side facing the glass fiber 1, said cutout being bridged by the fiber 1. A temperature-dependent change in refractive index and expansion of the fiber 1 leads to a measurable shift in the Bragg wavelength of the grating 11 with the temperature. The expansion of the fiber 1 with the temperature can be amplified by a suitably chosen material of the carrier body 2.

The arrangement of the sensor according to figure 3 differs from that of the sensor according to figures 2a and 2b essentially only through the presence of an inertial mass M. Otherwise, the sensor according to figure 3 structurally corresponds to the sensor according to figures 2a and 2b, and parts which are identical in both sensors are designated in figure 3 by the same reference symbols as in figures 2a and 2b.

In the sensor according to figure 3, the mass M is connected to the fiber 1 and exerts an expanding and/or contracting force on the Bragg grating 11, formed on the fiber 1, when the carrier body 2 is moved under acceleration.

In the case of the arrangement of the temperature-stable Bragg grating according to figure 4, the carrier body 2 is of composite rather than integral design. The composite carrier body 2 has a substrate body 2' and two sub-carrier bodies 2'', 2'' which are fixed on the substrate body 2' and separated from one another by an interspace 22'. On the two sub-carrier bodies 2'', 2'', the conductor 1, likewise comprising a glass fiber for example, is fixed at the two fixing points 21, 21 in such a way that one fixing point 21 is situated on one sub-carrier body 2'' and the other fixing point 21 is situated on the other sub-carrier body 2'', that the conductor 1 bridges the interspace 22', and that the grating 11 formed on the conductor 1 is arranged above

the interspace 22'.

The two sub-carrier bodies 2'', 2'' are fixed on the substrate body 2' in such a way that a section 20'', 20'' - adjoining the interspace 22' - of each sub-carrier body 2'', 2'' is not connected to the substrate body 2' and can freely expand and/or contract in the event of a change in temperature relative to the substrate body 2'.

The material of the substrate body 2' and the material of the two sub-carrier bodies 2'', 2'' are coordinated with one another in such a way that the interspace 22' between the sub-carrier bodies 2'', 2'' is narrowed and/or widened on account of a temperature-dictated expansion and/or contraction of the sections 20'', 20'' of the two sub-carrier bodies 2'', 2''. By way of example, the sub-carrier bodies 2'', 2'' are composed of a material having a thermal expansion coefficient $\alpha > 0$ and the substrate body 2' is composed of a material having a smaller thermal expansion coefficient relative to said coefficient α, preferably a vanishingly small thermal expansion coefficient.

A narrowing of the interspace 22' brought about by a change in temperature counteracts an expansion of the conductor 1 and hence of the grating 11 brought about by said change in temperature. A widening of the interspace 22' brought about by a change in temperature counteracts a contraction of the conductor 1 and hence of the grating 11 brought about by said change in temperature.

The material of the substrate body 2', the material of the two sub-carrier bodies 2'', 2'' and the material of the conductor 1 are preferably coordinated with one another in such a way that the narrowing of the interspace 22' brought about by a change in temperature essentially exactly cancels the expansion of the conductor 1 and hence of the grating 11 brought about

by said change in temperature, and the widening of the interspace 22' brought about by a change in temperature essentially exactly cancels the contraction of the conductor 1 and hence of the grating 11 brought about by said change in temperature.

This is the case, for example, if the material of the sub-carrier bodies 2'', 2'' and the material of the conductor 1 essentially have the same thermal expansion coefficient $\alpha > 0$ and if the thermal expansion coefficient of the material of the substrate body 2' is vanishingly small relative to said coefficient α.